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ANTI-FRATRICIDAL TECHNOLOGIES STUDY USING GROUNDWARS

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13. ABSTRACT (Maximum 200 words)

This study investigated contributions of anti-fratricidal technologies using the Groundwars combat simulation model. Technologies addressed were Second-Generation Forward Looking Infrared (FLIR), Battlefield Combat Identification System (BCIS), and Situational Awareness (SA). Target mis-identification (mis-ID) was also investigated. Both the reduction of fratricide and the increase in force effectiveness when employing anti-fratricidal technologies were examined. The following combat conditions were considered: (1) Mis-ID of targets not possible; Blue had good knowledge of Blue locations (i.e., Blue rarely engaged Blue, usually engaged Red); 2) Mis-ID of targets not possible; Blue had uncertain knowledge of Blue locations (i.e., Blue sometimes engaged Blue, disengaged Red); 3) Mis-ID of targets possible; Blue had good knowledge of Blue locations; and 4) Mis-ID of targets possible; Blue had uncertain knowledge of Blue locations. Blue would fire on classification. Second Generation FLIR anti-fratricidal technology option required firing on ID only. Study results showed for the zero mis-ID condition, BCIS provided significant contribution to Blue using First-Generation FLIR. When Blue employed Second-Generation FLIR, without considering mis-ID, all options (Engage on ID, BCIS, SA) showed similar benefits to the LER of the Blue force; however, all SA cases which allowed for some level of battlefield "confusion" continued to result in some level of fratricide. For the case where target mis-ID was possible, BCIS provided the most significant reduction of fratricide and increase in Blue effectiveness.

14. SUBJECT TERMS
Fratricide, Combat ID, GWARS, BCIS, Situational Awareness (SA), FLIR, Mis-identification (mis-ID), Groundwars

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Technical Review: Ginny Kistner, Combat Integration Division

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LIST OF ACRONYMS

1G	-	First Generation FLIR
2G	-	Second Generation FLIR
AMSAA	-	Army Materiel Systems Analysis Activity
APC	-	Armored Personnel Carrier
ARL	-	Army Research Laboratory
BCIS	-	Battlefield Combat Identification System
BFV	-	Bradley Fighting Vehicle
DIS	-	Distributed Interactive Simulation
DISSTAF	-	DIS Search and Target Acquisition Fidelity Experiment
FLIR	-	Forward Looking Infrared
FOR	-	Field of Regard
FOV	-	Field of View
GWARS	-	Groundwars
ID	-	Identification
IFV	-	Infantry Fighting Vehicle
Mis-ID	-	Mis-identification
N	-	Number of resolvable cycles across target
N50	-	Johnson Cycle (Line-Pair) Criteria
NFOV	-	Narrow Field of View
NVESD	-	Night Vision and Electronic Sensors Directorate
p	-	Probability
PINF	-	Probability of acquiring target given infinite time
PSA	-	Perfect Situational Awareness
SA	-	Situational Awareness
TBAR	-	Mean time to acquire
WFOV	-	Wide Field of Fiew

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ANTI-FRATRICIDAL TECHNOLOGIES STUDY USING GROUNDWARS

1. INTRODUCTION

This study was conducted to investigate the first-order contributions of available anti-fratricidal technologies in a force-on-force scenario. The study used the Groundwars Combat Simulation Model (GWARS) for the investigation. The three technologies addressed consisted of the Second Generation (2G) Forward Looking Infrared Radar (FLIR), Battlefield Combat Identification System (BCIS), and Situational Awareness (SA). The phenomenon of mis-identification of targets was also modeled as part of the investigation, using emerging trial results from the Distributed Interactive Simulation (DIS) Search and Target Acquisition Fidelity Experiment (DISSTAF I). This study examined not only the reduction of fratricide, but also the overall effectiveness of the force employing the anti-fratricidal technology.

The Groundwars scenario selected consisted of a BLUE Defense with a BLUE retrograde (retreating in the direction of the BLUE defensive position) tank squad versus a RED Offense. The fratricide possibilities consisted of fire from the BLUE defensive position onto the retreating BLUE tank squad.

2. MODEL DEVELOPMENT

2.1 Groundwars Model. Groundwars is a weapon systems effectiveness combat simulation model which provides the results of a land duel between two forces. The model simulates battle at the individual weapon system level and employs Monte Carlo probability theory as its primary solution technique. The simulation is stochastic and event sequenced.

Groundwars is an outgrowth of the TANKWARS model, version II, written in the mid 1980s by Fred Bunn of the Army Research Laboratory (ARL), Aberdeen Proving Ground, Maryland. [1] The original model has been modified by the U.S. Army Materiel Systems Analysis Activity (AMSAA) over the years to include numerous enhancements and new methodologies. As the AMSAA version grew and evolved, it was renamed Groundwars. The current version of the model is Groundwars Version 5.3. [2]

2.2 Fratricide Methodology. The model allows observers to acquire and engage both enemy and friendly units. [3] Upon acquisition of a target, the observer must decide whether or not to engage. This decision may be based on a number of reasons, among them being the observer's awareness of his and other friendly and enemy) positions on the battlefield. It is also possible that the observer is able to identify the acquired target through his target acquisition device. If so, and the target is deemed to be friendly, the observer will disengage and begin a new search process. If the target is identified as enemy, the observer will begin an engagement against the target.

2.3 Battlefield Combat Identification System (BCIS). BCIS is a query-response system, which is activated after an observer detects a target and decides to fire. Just prior to firing at the target, the firer queries the target (laser, radar frequency, or millimeter wave), and tries to elicit a response from the target. The query is placed just before the firing of the weapon to prevent the use of BCIS from interfering with the normal firing sequence of the gunner. If the target receives the signal and interprets it correctly, he will return a response to the firer. If the firer receives the reply and correctly interprets it, he will discontinue the firing sequence, disengage the target, and begin searching for new targets. Within Groundwars, the query-response process is modeled as a time delay and a probability, which are input. Given that an observer is going to engage a target, the BCIS time delay is applied and added to the aim time. The scheduled fire event is thus postponed by this amount of time. The probability of a correct query-response is tested just prior to the scheduled firing event to determine if a BCIS signal will alert the firer to disengage. A signal return of either friend or friend-in-sector will cause the firer to

discontinue the engagement, so the probability tested at this point is the sum of P(friend) and P(friend-in-sector). BCIS is only used at the beginning of an engagement versus each target. Once the firer begins to fire, he continues until the engagement is completed.

2.4 Situational Awareness (SA). In Groundwars, one can specify which target types each firer may engage. This allows fratricide to be modeled, but also eliminates the need for the simulation to calculate all of the engagement interactions that would take place between two units which would never realistically engage one another. This also allows the modeling of some type of "situational awareness" so that one can specify, for a given combat group, to what "areas" on the battlefield they may engage unknown targets, and what percentage of the time they will do this. So, in addition to specifying which target types each firer may engage, a probability, P(engage), is also specified for each firer/target pairing which represents the percentage of time the firer will attempt to engage an unknown target of this type (given a detection of an unknown target). For example, given that an observer, A, acquires a target, B, a check is made to determine if A is able to identify B through his sensor. The ability to do this is a function of the input data in the sensor file, the environmental and target conditions in the battle, and calculations based on Night Vision and Electronic Sensors Directorate's (NVESD's) ACQUIRE model (see later section). If A is able to identify B as friendly, he will break off the engagement. If A identifies it as an enemy, he will engage the target. If A is not able to identify B, he must make a decision whether to engage this unknown target. A random number is then drawn and tested against the probability P(engage) for this firer type/target type. If the test succeeds, A will engage B, otherwise he will disengage. Thus, this probability, P(engage), can be used in the model to simulate a form of situational awareness knowledge. For example, if a group C has SA that group D is friendly, one can specify that all unit types in group C have P(engage) equal to zero against all unit types in group D. If it is assumed that group C has no awareness that group D is friendly, one could specify P(engage) to be 1.0 and all firers in group C will engage unknown (i.e., not identified) targets in group D. One can also specify probabilities of P(engage) between zero and one to represent some level of confusion on the battlefield, less than perfect situational awareness, or less than optimal decision-making. Thus, the SA in this study is used only to assist in engagement decisions, with no attempt to address broader engagement planning.

2.5 Search/Target Acquisition. Groundwars allows the user to play optical, thermal, or millimeter wave devices. For optical and thermal devices, the model uses a form of the NVESD target

acquisition methodology to determine acquisition capability. Groundwars models both wide and narrow field of view search. For observers having both wide and narrow field of view on their sensors, Groundwars starts their search process with observers initially using their wide field of view (WFOV). After successful acquisition in WFOV, the observer will switch to narrow field of view (NFOV) and attempt to find the target based on the desired level of target discrimination for engaging in NFOV. If the target is not acquired in NFOV, the observer will switch back to WFOV to continue searching.

2.5.1 NVESD ACQUIRE Methodology in Groundwars. The level of target discrimination desired is specified in the sensor input file for both WFOV and NFOV. The Johnson Line Pair Criteria, N50, are an empirically determined set of values used to define four levels of target discrimination. These values, N50, are the number of resolved cycles such that half the observers can discriminate a target at the respective level. The discrimination levels are defined as follows:

Detection is the ability of an observer to distinguish that an object is of military interest.

Classification is the ability to distinguish a target by general type; i.e., a tracked versus a wheeled vehicle.

Recognition is the ability to distinguish between two targets of similar type; i.e., between two types of tracked vehicles, such as APCs and tanks.
Identification is the ability to discriminate the exact model of a target; i.e., a T72 or M1 tank.

In order to reflect the combination of vertical and horizontal resolution in the two dimensional Minimum Resolvable Temperature Difference (2D MRTD), the following recommendations have been made by NVESD for N50 values when using 2D MRTD methodology:

Detection	-	0.75
Classification	-	1.50
Recognition	-	3.00
Identification	-	6.00

These cycle criteria are used across all sensors: DVO, TV, I2, and thermal imagers (both first and second generation).

Groundwars uses equations developed at NVESD to calculate P-Infinity (probability of acquisition) and TBAR (mean time to acquire) based upon various environmental, battlefield, sensor, and target conditions during the simulation. Groundwars uses the following equations:

$$TBAR = \frac{3.4\left(\frac{FOR}{FOV}\right)}{PINF}\ FOR\ PINF < 0.9$$

$$\text{TBAR} = \frac{6.8\left(\frac{FOR}{FOV}\right)}{N/N50}\ \text{FOR PINF} \geq 0.9$$

$$\text{TDETECT} = \text{-TBAR}\left(\ln\left[1 - \frac{U(0,1)}{PINF}\right]\right)$$

$$PINF = \frac{\left(\frac{N}{N50}\right)^{E}}{1 + \frac{N}{N50}^{E}}$$

$$\text{E} = 2.7 - 0.7\left(\frac{\text{N}}{\text{N50}}\right)$$

where

N = number of resolvable cycles across the target
N50 = number of resolvable cycles that must be presented for 50 percent of the observer population to perform the task (i.e., detection, recognition, etc.).
TBAR = Mean time to acquire
PINF = Probability of acquiring a target given infinite time
FOR = Observer's Field of Regard
FOV = Sensor Field of View
U[0,1] = Uniform random number from 0.0 to 1.0

PINF (P-Infinity) and TBAR are calculated separately for WFOV and for NFOV. The level of resolvable cycles used for each FOV depends upon the input criteria specified for each. Typically, for Groundwars, the detection level is used for WFOV, and recognition, classification, or identification is used for NFOV.

A uniform [0,1] random number, R, is drawn at the beginning of each replication in Groundwars for each observer, and is assigned to that observer for the duration of the battle. The observer's random number is used for all P-Infinity tests for that observer for the duration of the battle for the replication.

When an observer is searching for targets, the Random Number, R, for the observer is examined, and if it less than or equal to P-Infinity(WFOV, Detect), a time to acquire the target in WFOV is calculated and scheduled (put into the simulation's time-ordered event queue). If it is greater than P-Infinity, the observer will continue searching for targets.

At the scheduled WFOV-detect time, the observer switches to NFOV. R is again examined, and is now compared to P-Infinity (NFOV, Classification). If R is less than or equal to P-Infinity, then a time to classify the target in NFOV is calculated. If the test of R versus P-Infinity had failed, the observer will switch back to WFOV and continue searching for new targets. If no new targets are found in TLOOK seconds (input, typically 30 seconds), the observer will switch to NFOV and go through the process of attempting to NFOV-classify the target again.

2.5.2 Mis-Identification (Mis-ID). Based on information from combat and from field tests, a portion of the time, observers will mis-identify targets. Sometimes, one type of target will be mis-identified as another type of the same force (e.g., a BMP thought to be a T80). Other times, a unit from one force may be thought to be a unit from the other. This latter type of situation has, of course, more serious consequences, and may lead to either fratricide, or failure to engage the enemy.

The question as to how to model mis-identification in Groundwars is really a question of understanding or interpretation of the target acquisition equations from NVESD's ACQUIRE model. The calculation of P-Infinity for Identification (6.0 line pairs) gives the probability, P, of identifying the target. Then the quantity (1 - P) is the probability of not identifying the target. The question is, does the probability of mis-identification fall within the quantity P, or (1 - P)? There have been arguments for both interpretations. During the undertaking of this study, it was first thought that the probability of mis-identification should be part of P (Methodology 1 described below). Then, arguments to consider it as part of (1 - P) were put forth (Methodology 2 described below). Finally, by the end of the study, it was decided that study results based on using Methodology 1 would be briefed. Since then, the correct way to interpret mis-ID has continued to be studied, and current thoughts will probably result in yet a different way to model the phenomenon of mis-ID than was used in this study. However, this paper will present the results from both methodologies used during the study (mid-1996).

2.5.2.1 Mis-ID Methodology 1. Based on equations from NVESD's ACQUIRE model, the calculation of P-Infinity Identification (6.0 line pairs) gives the probability, P, of identifying the target. The quantity (1 - P) is the probability of not identifying the target. In this interpretation, the probability of mis-identifying the target as one from the opposite force, M, is considered as part of the probability P. Thus, the probability P as calculated from NVESD gives the probability of 'making an ID call on the target' which can result in a correct call or an incorrect (or mis-ID) call. The quantity (1 - P) is the probability of not identifying the target, but also 'not making an ID call.' The mis-ID data used for the study are probabilities of mis-ID broken down by mis-identifying BLUE as RED and mis-identifying RED as BLUE. Data for mis-identifying BLUE as another BLUE type and RED as a different RED type were also available and used. In this study, this type of mis-ID was considered the same as a correct ID, since the behavior of the observer would be the same. The probability of this type of mis-ID only needed to be sampled explicitly during Methodology 2.

The following table shows how the probabilities are used in methodology 1:

Table 1. Application of Mis-ID Methodology 1 Probabilities.

Results of NVESD ACQUIRE P-Infinity Identification calculation:		
Making an ID call: P		No ID call Made: (1 - P)
Results of applying the mis-ID probability M:		
Correct ID: P * (1 - M)	Incorrect-ID: P * M	No ID (Target Considered Unknown): 1 - P

The data used for mis-identification for Methodology 1 from DISSTAF I were as follows (Table 2):

Table 2. Mis-ID Methodology 1 Probabilities.

For First Generation FLIR:	M (BLUE called RED) = .14
	M (RED called BLUE) = .49
For Second Generation FLIR:	M (BLUE called RED) = .09
	M (RED called BLUE) = .32

Although Second Generation FLIR (2G) data were not collected from DISSTAF, it was desired to run some cases using Second Generation FLIR. At the time, it was thought that to use the same First Generation FLIR mis-ID values for Second Generation FLIR mis-ID would be a high and unfair assumption. Since Second Generation FLIR is a better sensor than First Generation FLIR, it was thought that the mis-ID rate might be smaller. As a first-order estimate, it was decided to scale the First Generation FLIR

mis-ID values by the same ratios as the ACQUIRE-model calculated values of P-Infinity (Identification) for First Generation FLIR and Second Generation FLIR. The ratio used was 0.65. This represented the average ratio of the two P-Infinity values.

2.5.2.2 Mis-Identification Methodology 2. Based on equations from NVESD's ACQUIRE model, the calculation of P-Infinity Identification (6.0 line pairs) gives the probability, P, of identifying the target. The quantity (1 - P) is the probability of not identifying the target. In this interpretation, the probability of mis-identifying the target as one from the opposite force, M, is considered as part of the probability (1 - P). The probability of mis-identifying the target as another type from the same force, m, is also considered as part of the probability (1 - P).

Thus, the probability P as calculated from NVESD gives the probability of 'making a correct ID call on the target.' The quantity (1 - P), the probability of not identifying the target, in this case, also includes mis-identifying the target (M and m).

The following table shows how the probabilities are used in Methodology 2:

Table 3. Application of Mis-ID Methodology 2 Probabilities.

Results of NVESD ACQUIRE P-Infinity Identification calculation:	
Making a correct ID: P	Not Making a correct ID: 1-P
Results of applying the mis-ID probabilities M and m:	
Correct-ID: P	Incorrect ID (BLUE called RED or RED called BLUE): (1 - P) * M
Incorrect ID (but treated as Correct ID): (1 - P) * m	No ID (Target Unknown): (1 - P) * (1 - (M + m))

The data used for mis-identification for Methodology 2 from DISSTAF I were as follows (Table 4):

Table 4. Mis-ID Methodology 2 Probabilities.

m (RED called other RED)	= .00
M (RED called BLUE)	= .11
m (BLUE called other BLUE)	= .05
M (BLUE called RED)	= .04

By the time the Methodology 2 cases were run, it was thought that the scaling technique that was used to estimate the Second Generation FLIR mis-ID probabilities was not justified.

Therefore, the same First Generation FLIR (1G) mis-ID probabilities were used for Second Generation FLIR mis-ID values for Methodology 2.

3. STUDY

3.1 Scenario. The Groundwars scenario consisted of a BLUE Defense with a BLUE retrograde tank squad versus a RED Offense with Overwatch. The retrograde tank squad is retreating in the direction of the BLUE defensive position. The BLUE defensive force consists of 8 tanks and 5 infantry vehicles. The BLUE retrograde tank squad consists of 10 tanks. The RED force includes 40 maneuver tanks with 5 infantry vehicles in overwatch. The fratricide possibilities consist of fire from the BLUE defensive position onto the retreating BLUE tank squad. Graphical representation of the scenario is shown in Figure 1.

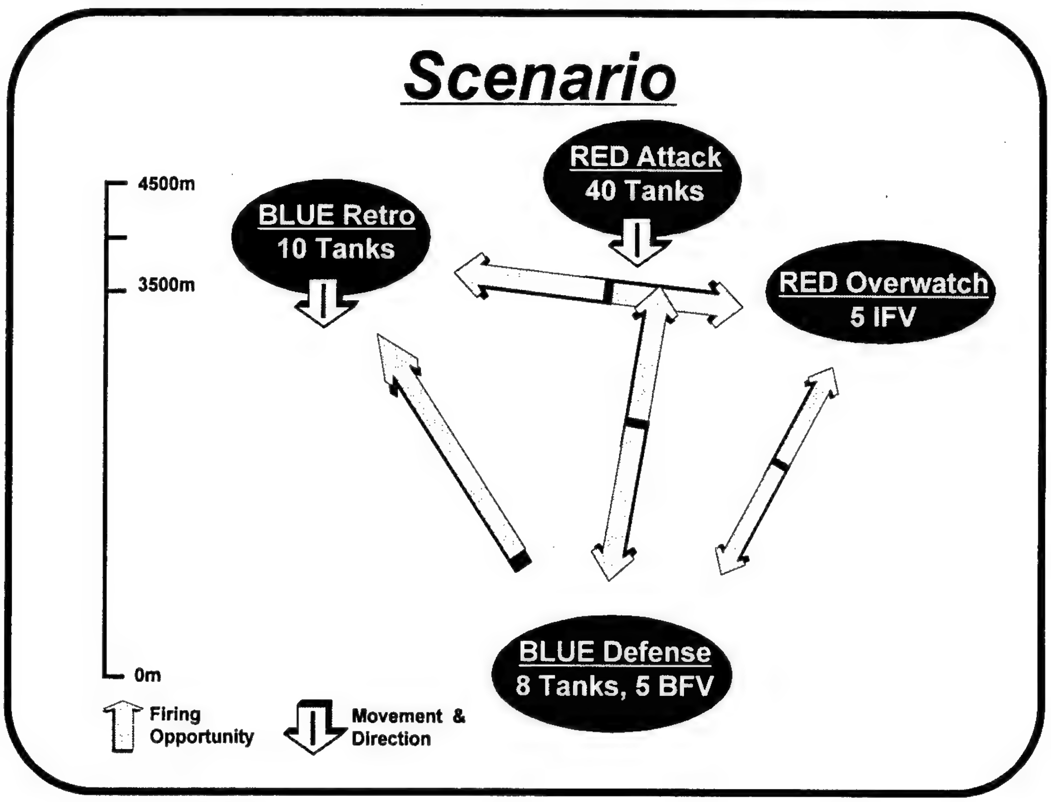

Figure 1. Groundwars Scenario.

3.2 Methodology Representation.

3.2.1 Without Mis-ID. The first set of cases were run without modeling the phenomenon of target mis-identification. The following five sections describe the methodology used for these cases.

3.2.1.1 Base. The base case consisted of BLUE engaging on (at least) classification. After the observer detects a target in WFOV, and classifies in NFOV, the model will determine if identification has been achieved (according to the NVESD equations). If ID occurs, the firer will either engage if the target is an enemy, or disengage if it's a friend. If ID fails (thus the target type is unknown), the firer will engage. See Figure 2 for a graphical representation.

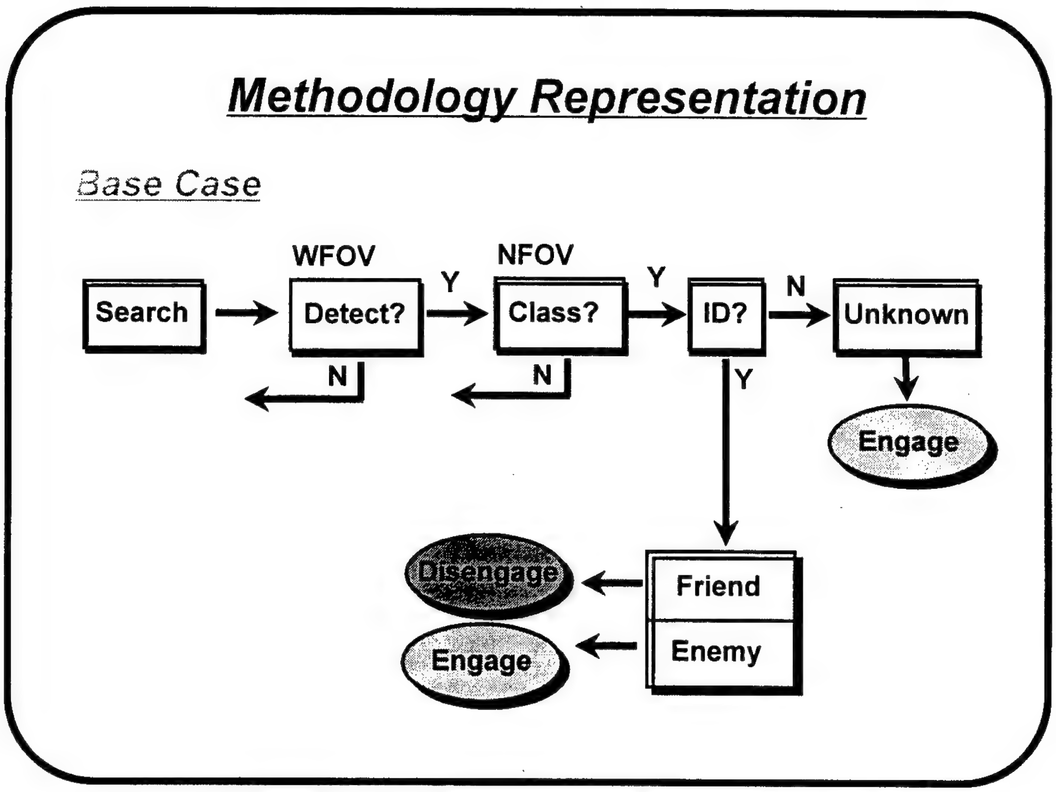

Figure 2. Base Case Methodology Representation - No mis-ID.

3.2.1.2 Engage on ID. In this case the firer will engage a target only if he has identified it as an enemy. The only difference between the base case and this one, is that here the firer will disengage the target if ID has not been achieved (disengage on unknown target). See Figure 3 for a graphical representation.

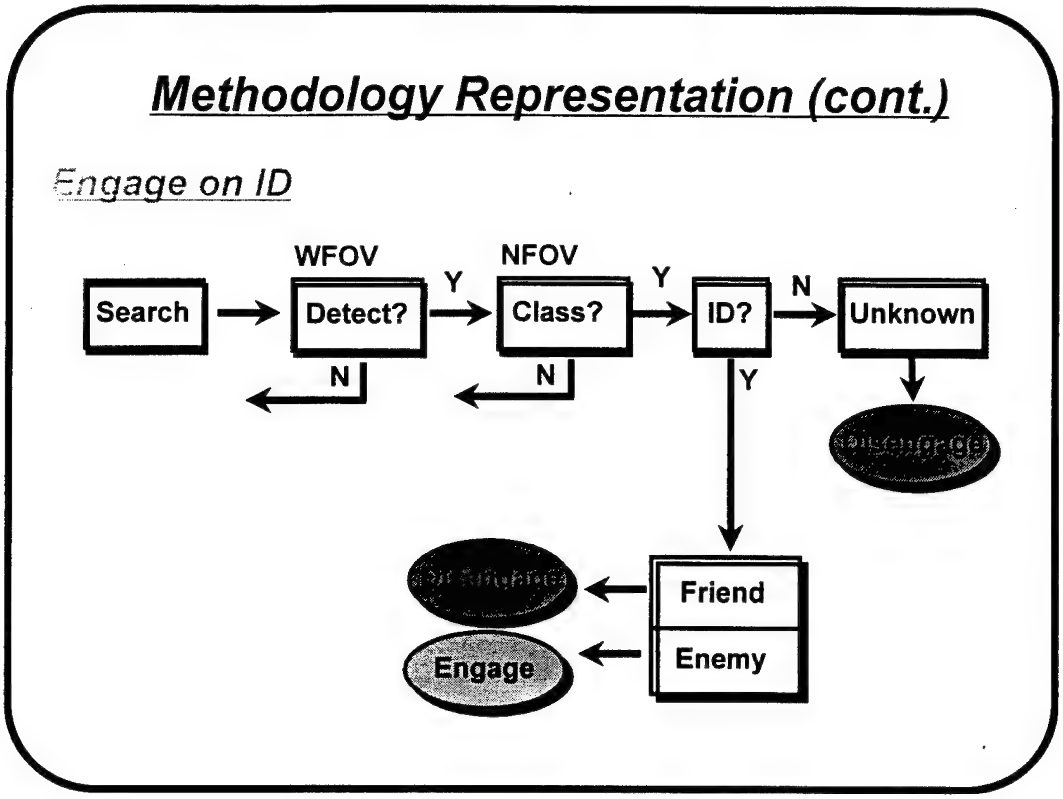

Figure 3. Engage on ID Methodology Representation - No mis-ID.

3.2.1.3 BCIS. Here the firer will use his BCIS to attempt to obtain information about a target before firing. If the target is identified as friendly by the observer's sensor device, he will disengage. If it is identified as an enemy, he will engage. If the target is not identified, and the BCIS signal is returned (meaning friend or friend-in-sector), he will disengage; if no BCIS signal is returned, he will engage. See Figure 4 for a graphical representation. Note, in all cases, a CID signal is sent just prior to an attempted engagement (doctrine).

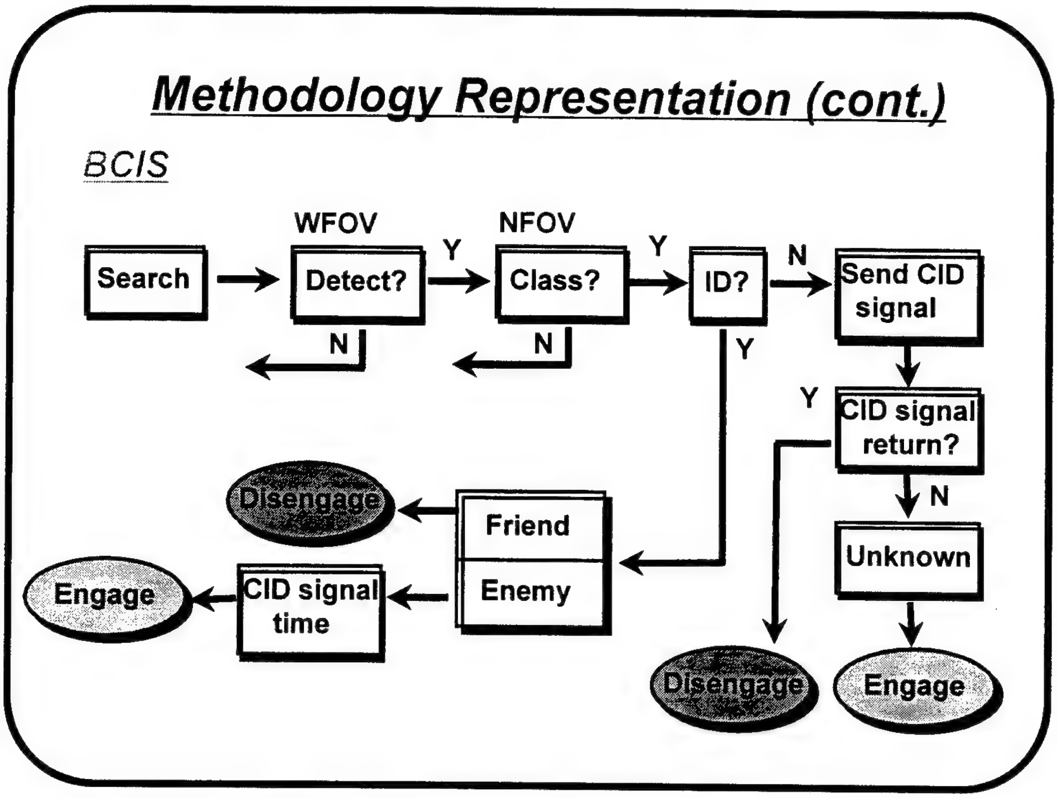

Figure 4. BCIS Methodology Representation - No mis-ID.

3.2.1.4 Situational Awareness. In this case, it is assumed that BLUE has some kind of situational awareness (SA) information to use to make a decision on when to engage an unknown (not identified through the sensor device) target. As described in the earlier section on SA, the P(engage) probability is used to determine whether to engage an unknown target. A different probability is used, based on whether the target is from the area where BLUE expects RED to be located, or from another area. The actual criteria used in the model for this is simply whether the target is really a RED or a BLUE. Different values of P(engage) probabilities were used for different SA cases to represent various levels of confusion on the battlefield. See Figure 5 for a graphical representation.

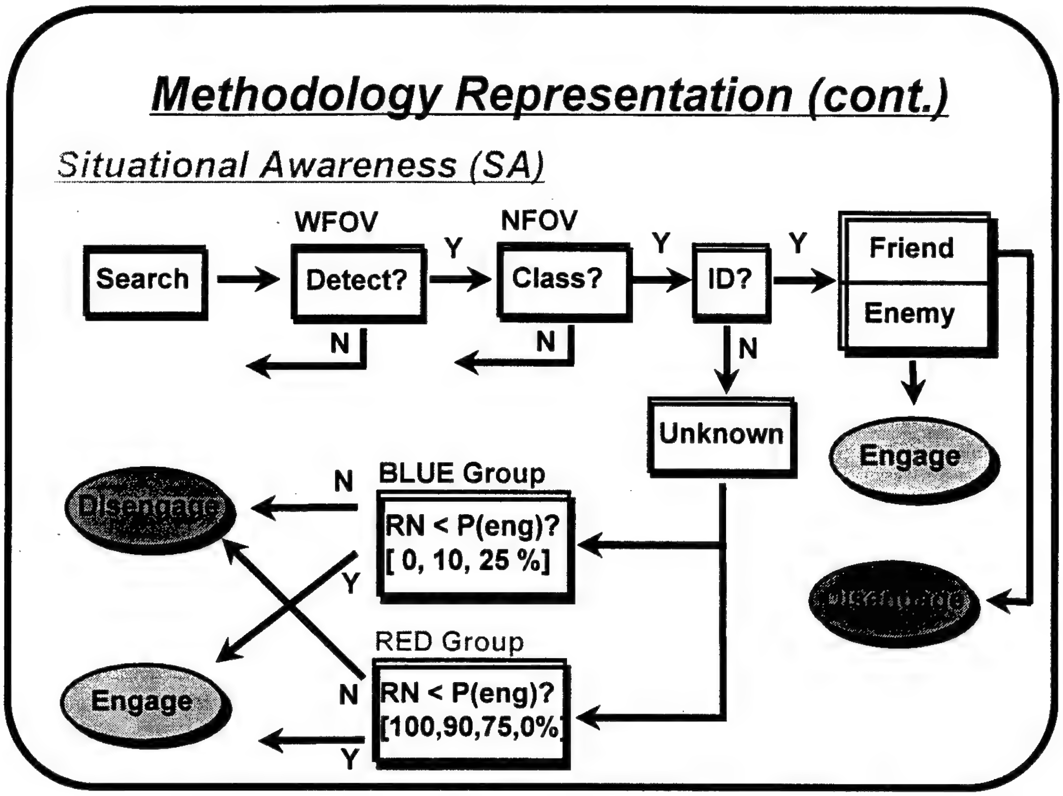

Figure 5. Situational Awareness (SA) Methodology Representation - No mis-ID.

3.2.1.5 Perfect Situational Awareness. Since the aim of exploring the anti-fratricidal technologies is to prevent BLUE from engaging friendly forces (while also maximizing BLUE's correct decisions to engage enemy forces), this case was run to obtain an upper bound on how well BLUE might perform in this capacity, and perhaps put in perspective the potential benefits of the anti-fratricidal technologies explored. It is not intended to necessarily reflect reality. Here, BLUE is assumed to know exactly where RED and BLUE forces are located, does not spend any time searching in the direction of the BLUE retrograde force, and always engages a classified, but 'unknown' RED target. See Figure 6 for a graphical representation.

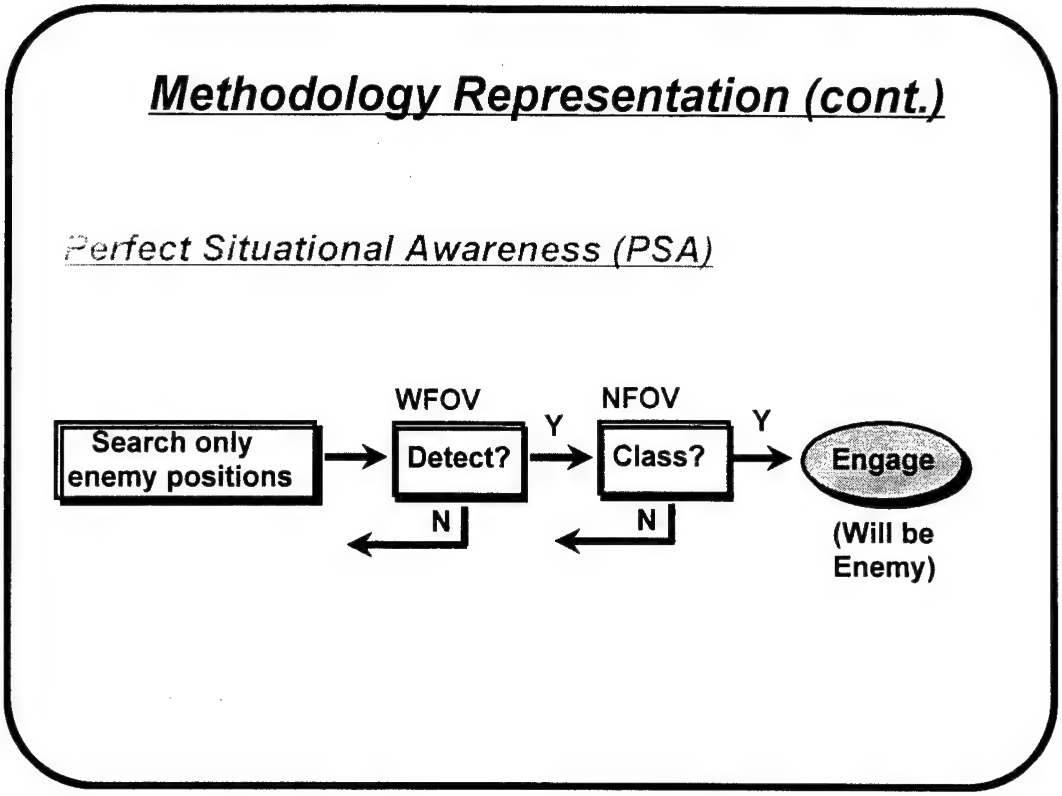

Figure 6. Perfect Situational Awareness (PSA) Methodology Representation - No mis-ID.

3.2.2 Mis-ID Methodology 1. In the set of cases run with mis-ID Methodology 1, the mis-ID probabilities are applied after it is determined that an ID call is made (NVESD calculated P-Infinity test succeeds). The decision to engage or disengage is made based on whether the target is thought to be friendly or enemy. The next five figures show graphical representations of the methodologies for the five different types of cases run with mis-ID Methodology 1.

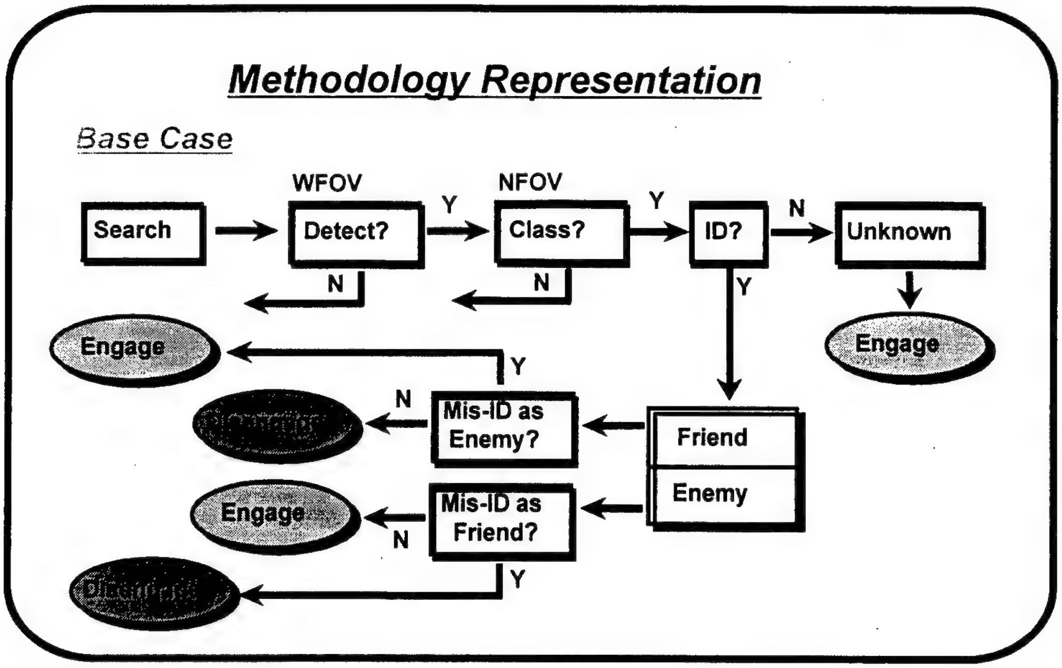

Figure 7. Base Case - Mis-ID Methodology 1.

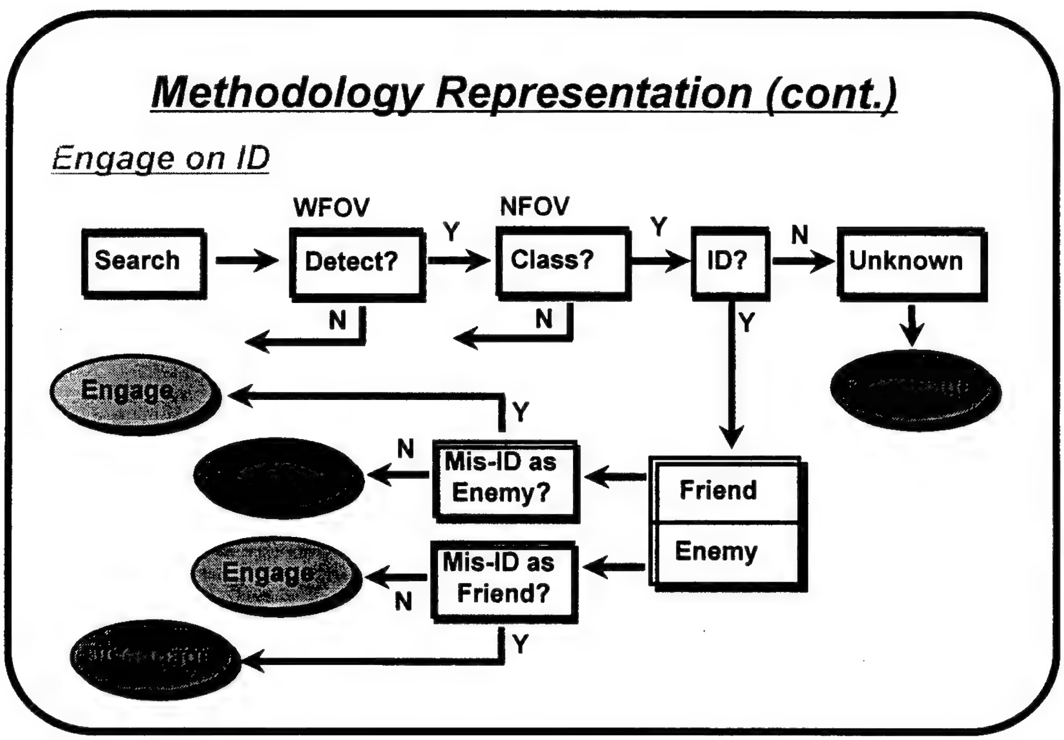

Figure 8. Engage on ID - Mis-ID Methodology 1.

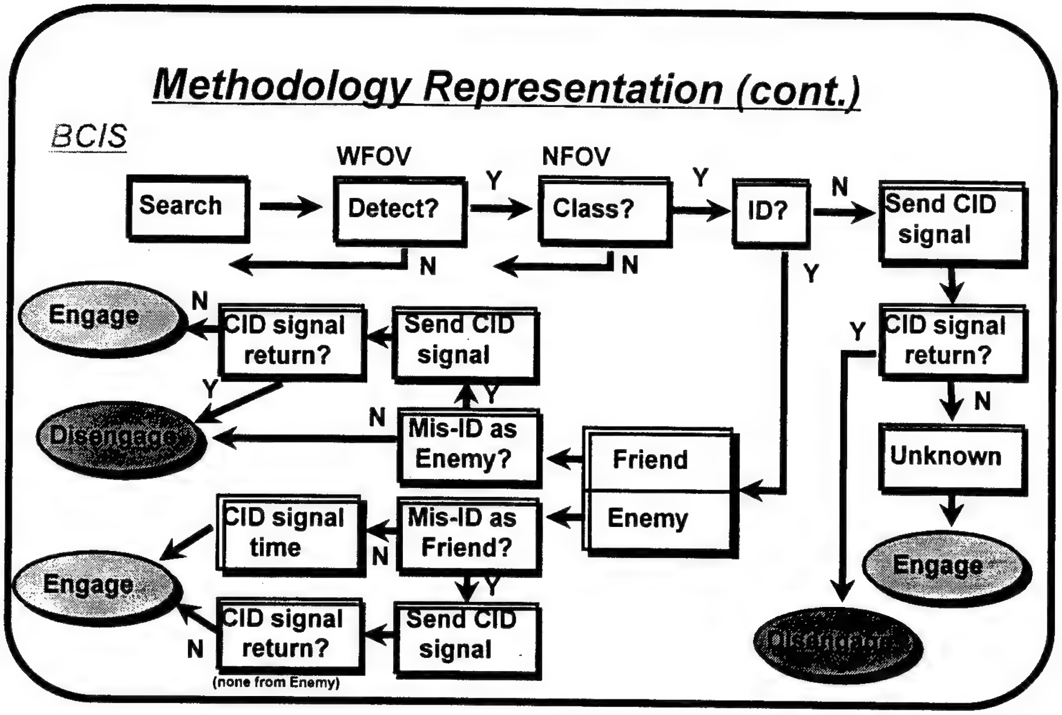

Figure 9. BCIS - Mis-ID Methodology 1.

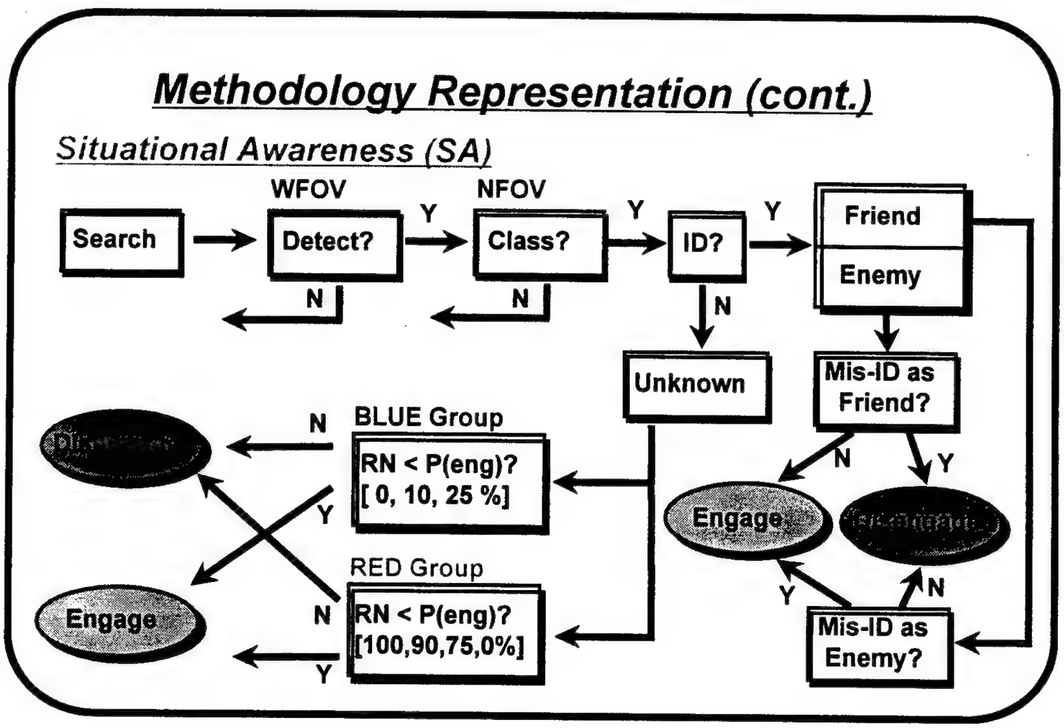

Figure 10. SA - Mis-ID Methodology 1.

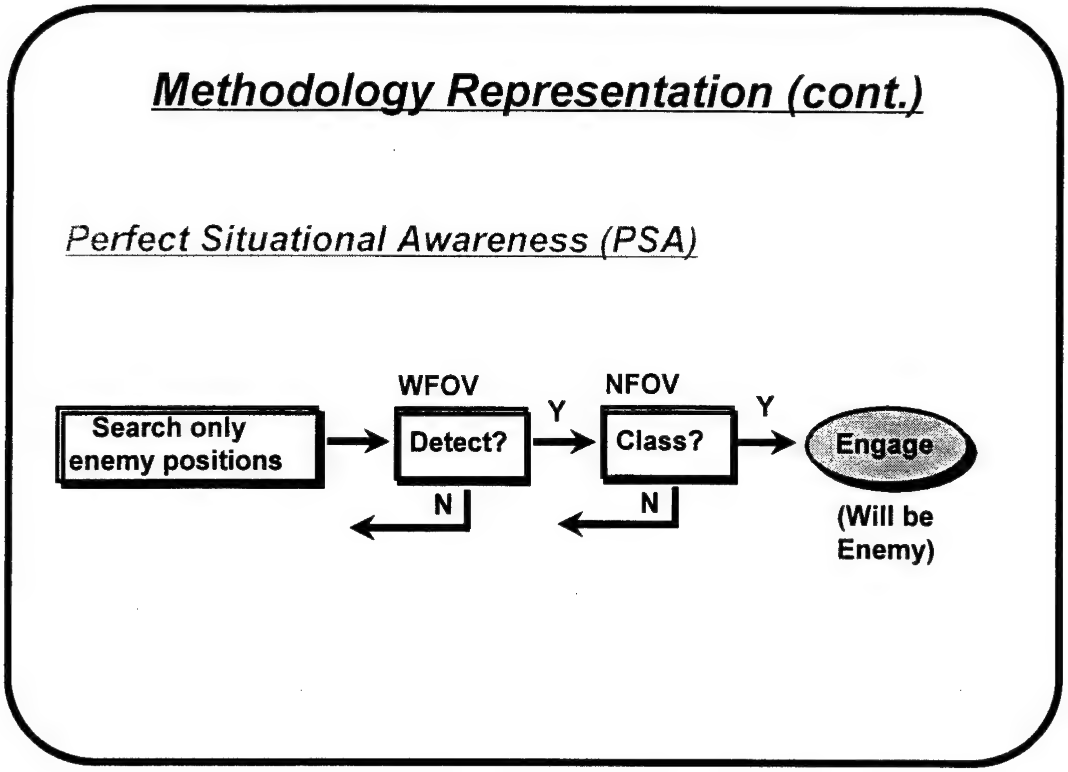

Figure 11. PSA - Mis-ID Methodology 1.

3.2.3 Mis-ID Methodology 2. In the set of cases run with mis-ID Methodology 2, the mis-ID probabilities are applied only on targets that the observer failed to ID. The general procedure to determine into which class the perceived target falls is illustrated in Figure 12. This logic is used for the five different case types, which are repeated for this methodology. As before, the observer will engage the target based on his perception of whether the target is a friend or enemy.

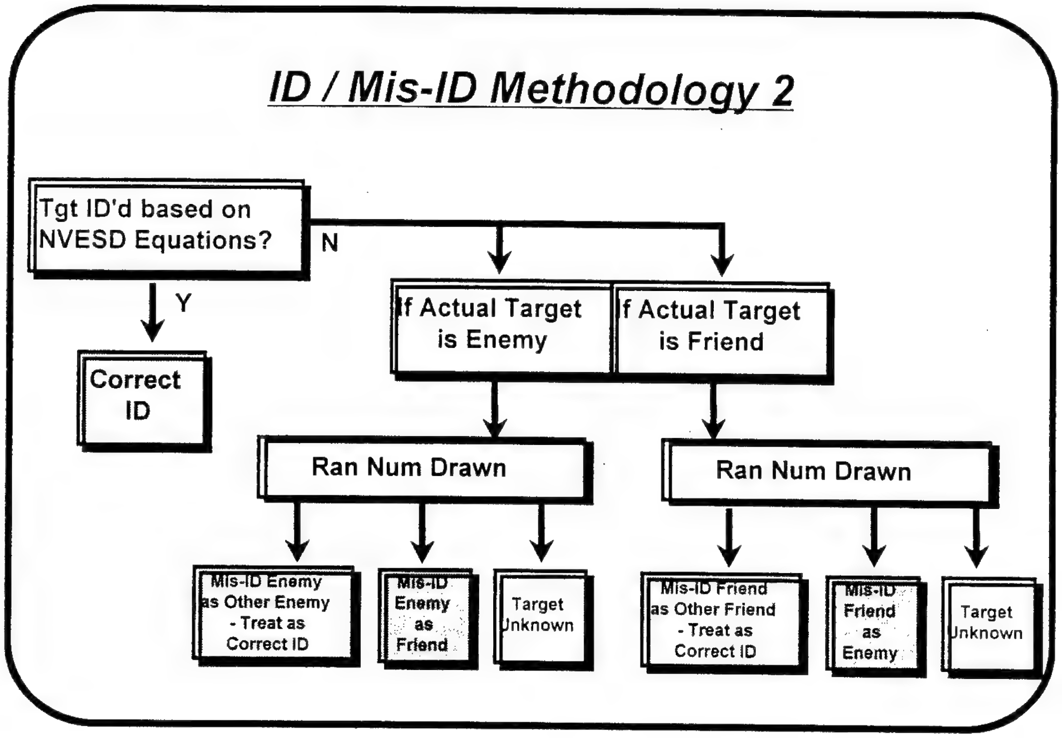

Figure 12. ID/Mis-ID Methodology 2.

3.3 Run Matrix. The following table lists the 48 cases that were run for the study. There are basically eight different types of cases. Each set of eight were run for BLUE using First Generation FLIR, and for BLUE using Second Generation FLIR. Each of these 16 cases were run for the following three situations: 1) No mis-identification played; 2) Mis-ID Methodology 1; and 3) Mis-ID methodology 2.

Each set consisted of eight cases as described in the table below. Note that there were four different variations played for the SA cases. The SA-100-0 case represents the situation where BLUE always makes the correct decision on engaging or disengaging an unknown target. The SA-90-10 cases represent the situation where there is some confusion on the battlefield, and BLUE makes an incorrect decision 10 percent of the time when he has an unknown BLUE target, and 10 percent of the time when he has an unknown RED target. The SA-75-25 cases investigate the results of assuming a little more confusion on the battlefield. The SA-0-0 cases represent a conservative engagement policy by BLUE in that he will always disengage an unknown target, except for RED overwatch. In all SA cases, the assumption was that the RED overwatch positions were distinct enough that BLUE would still engage an unknown target detected there.

Table 5. Groundwars Case Matrix.

Sensor Cases	Mis-ID	Anti-Frat BLUE	RED	Technology	Description
1	No	1G	1G	Base	Engage all unknown (not ID'd) targets
2	No	1G	1G	Engage on ID	Engage on ID only
3	No	1G	1G	BCIS	Engage all BCIS-unknown targets
4	No	1G	1G	SA 100- 0	Engage unk RED Group-100% BLUE Group- 0%
5	No	1G	1G	SA 90-10	Engage unk RED Group- 90% BLUE Group-10%
6	No	1G	1G	SA 75-25	Engage unk RED Group- 75% BLUE Group-25%
7	No	1G	1G	SA 0- 0	Engage unk RED Group- 0% BLUE Group- 0%
8	No	1G	1G	Perfect SA	No search or acquisition of friendly
9	No	2G	1G	Base	Engage all unknown (not ID'd) targets
10	No	2G	1G	Engage on ID	Engage on ID only
11	No	2G	1G	BCIS	Engage all BCIS-unknown targets
12	No	2G	1G	SA 100- 0	Engage unk RED Group-100% BLUE Group- 0%
13	No	2G	1G	SA 90-10	Engage unk RED Group- 90% BLUE Group-10%
14	No	2G	1G	SA 75-25	Engage unk RED Group- 75% BLUE Group-25%
15	No	2G	1G	SA 0- 0	Engage unk RED Group- 0% BLUE Group- 0%
16	No	2G	1G	Perfect SA	No search or acquisition of friendly
17	1	1G	1G	Base	Engage all unknown (not ID'd) targets
18	1	1G	1G	Engage on ID	Engage on ID only
19	1	1G	1G	BCIS	Engage all BCIS-unknown targets
20	1	1G	1G	SA 100- 0	Engage unk RED Group-100% BLUE Group- 0%
21	1	1G	1G	SA 90-10	Engage unk RED Group- 90% BLUE Group-10%
22	1	1G	1G	SA 75-25	Engage unk RED Group- 75% BLUE Group-25%
23	1	1G	1G	SA 0- 0	Engage unk RED Group- 0% BLUE Group- 0%
24	1	1G	1G	Perfect SA	No search or acquisition of friendly
25	1	2G	1G	Base	Engage all unknown (not ID'd) targets
26	1	2G	1G	Engage on ID	Engage on ID only
27	1	2G	1G	BCIS	Engage all BCIS-unknown targets
28	1	2G	1G	SA 100- 0	Engage unk RED Group-100% BLUE Group- 0%
29	1	2G	1G	SA 90-10	Engage unk RED Group- 90% BLUE Group-10%
30	1	2G	1G	SA 75-25	Engage unk RED Group- 75% BLUE Group-25%
31	1	2G	1G	SA 0- 0	Engage unk RED Group- 0% BLUE Group- 0%
32	1	2G	1G	Perfect SA	No search or acquisition of friendly
33	2	1G	1G	Base	Engage all unknown (not ID'd) targets
34	2	1G	1G	Engage on ID	Engage on ID only
35	2	1G	1G	BCIS	Engage all BCIS-unknown targets
36	2	1G	1G	SA 100- 0	Engage unk RED Group-100% BLUE Group- 0%
37	2	1G	1G	SA 90-10	Engage unk RED Group- 90% BLUE Group-10%
38	2	1G	1G	SA 75-25	Engage unk RED Group- 75% BLUE Group-25%
39	2	1G	1G	SA 0- 0	Engage unk RED Group- 0% BLUE Group- 0%
40	2	1G	1G	Perfect SA	No search or acquisition of friendly
41	2	2G	1G	Base	Engage all unknown (not ID'd) targets
42	2	2G	1G	Engage on ID	Engage on ID only
43	2	2G	1G	BCIS	Engage all BCIS-unknown targets
44	2	2G	1G	SA 100- 0	Engage unk RED Group-100% BLUE Group- 0%
45	2	2G	1G	SA 90-10	Engage unk RED Group- 90% BLUE Group-10%
46	2	2G	1G	SA 75-25	Engage unk RED Group- 75% BLUE Group-25%
47	2	2G	1G	SA 0- 0	Engage unk RED Group- 0% BLUE Group- 0%
48	2	2G	1G	Perfect SA	No search or acquisition of friendly

3.4 Results. The next six figures show model results. Each figure shows a set of eight cases, with bar graphs showing the number of BLUE losses (left Y-axis), and small square markers showing LER, Loss Exchange Ratio (right Y-axis). The total height of the bars represent the total losses to the BLUE side. The lighter, lower part of each bar represents BLUE losses due to enemy fire. The upper, darker part of each bar represents those losses due to friendly fire. The LERs shown as small black squares are a ratio of RED losses divided by BLUE losses. Each LER box is bounded by a clear rectangular area which represents an upper and lower bound for a 95 percent confidence interval about the LER.

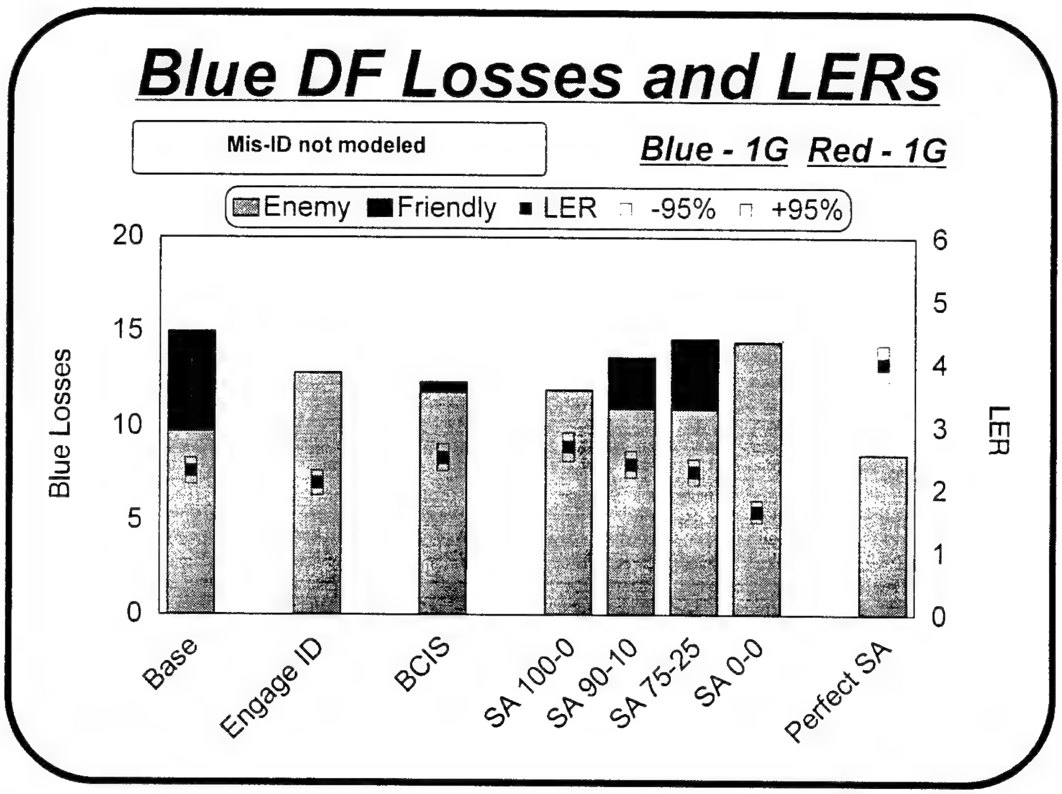

Figure 13. BLUE Direct-Fire Losses and LERs, No Mis-ID, 1G/1G.

Figure 13 shows results for BLUE using First Generation FLIR (1G), without mis-identification. The base case shows that 35 percent of BLUE's losses were due to friendly fire. Restricting BLUE to firing only on identified targets resulted in no losses due to friendly fire, and about a drop of about 15 percent in overall losses. However, the restrictive firing policy also deprived BLUE of achieving as many RED kills as in the base case, and ended up actually lowering BLUE's LER slightly. The BCIS case also shows a drop in overall BLUE losses comparable to the Engage on ID Case, with BLUE losses due to friendly fire only

about 4 percent of overall BLUE losses. Unlike the restrictive firing policy of Engage on ID case, the BCIS case resulted in more RED kills than case 2, and the LER here is actually higher than either of the first two cases. The SA-100-0 case, where BLUE always makes the correct decision on engaging or disengaging an unknown target based on excellent situational awareness, shows BLUE performing about as well as in the BCIS case. When error is introduced (SA cases 90-10 and 75-25) due to position confusion, etc., BLUE's performance falls off considerably, with fratricide levels back up to 20 and 25 percent of casualties, and LERs dropping to about the base case level. The BLUE conservative engagement policy case, SA-0-0, although preventing fratricide, also resulted in decreased RED kills and resulted in the worst performance by the BLUE force, with LER of 1.65. The Perfect SA (PSA) case with LER of 4.0, while probably unrealistic to expect to occur, especially in a situation where both friendly and enemy positions are in close proximity, nevertheless shows an "upper bound" LER as a standard to measure against. Likewise, the PSA case results shown on subsequent charts also provide an upper limit to effectiveness.

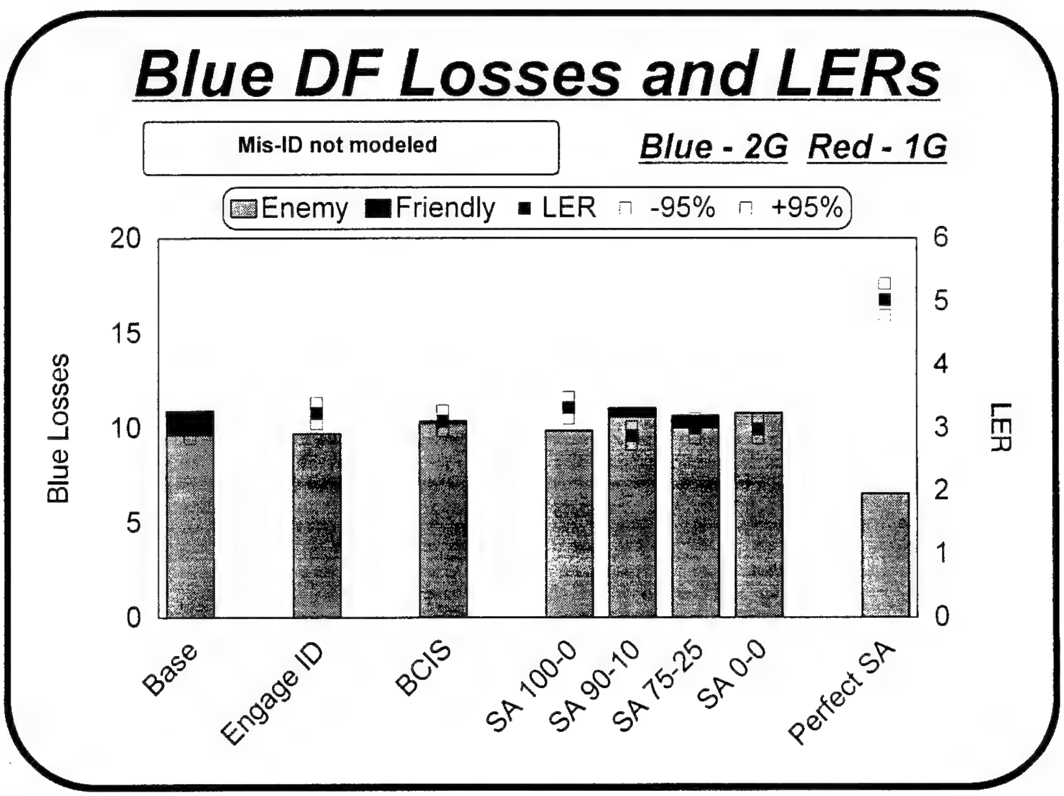

Figure 14. BLUE Direct-Fire Losses and LERs, No Mis-ID, 2G/1G.

Figure 14 shows results for BLUE using Second Generation FLIR (2G), without mis-identification. Compared to the First

Generation FLIR cases, BLUE performs better in general because of his increased target acquisition capabilities. Not only can he acquire targets at further range, but he can identify targets more frequently, given a detection. The base case here shows that 11 percent of BLUE losses were due to fratricide. As in the Engage on ID First Generation FLIR case, the Engage on ID case here again shows no losses due to fratricide. But now, there is an improvement to the BLUE force effectiveness as evidenced by the better LER (3.2 to 3.0) when BLUE adopts the policy of engaging on ID only. The improvement in ability to ID targets through the Second Generation FLIR now makes this policy worthwhile. Both the BCIS and SA-100-0 cases also reduce fratricide to near-zero and produce LERs comparable to the Engage on ID case. The other SA cases are slightly worse.

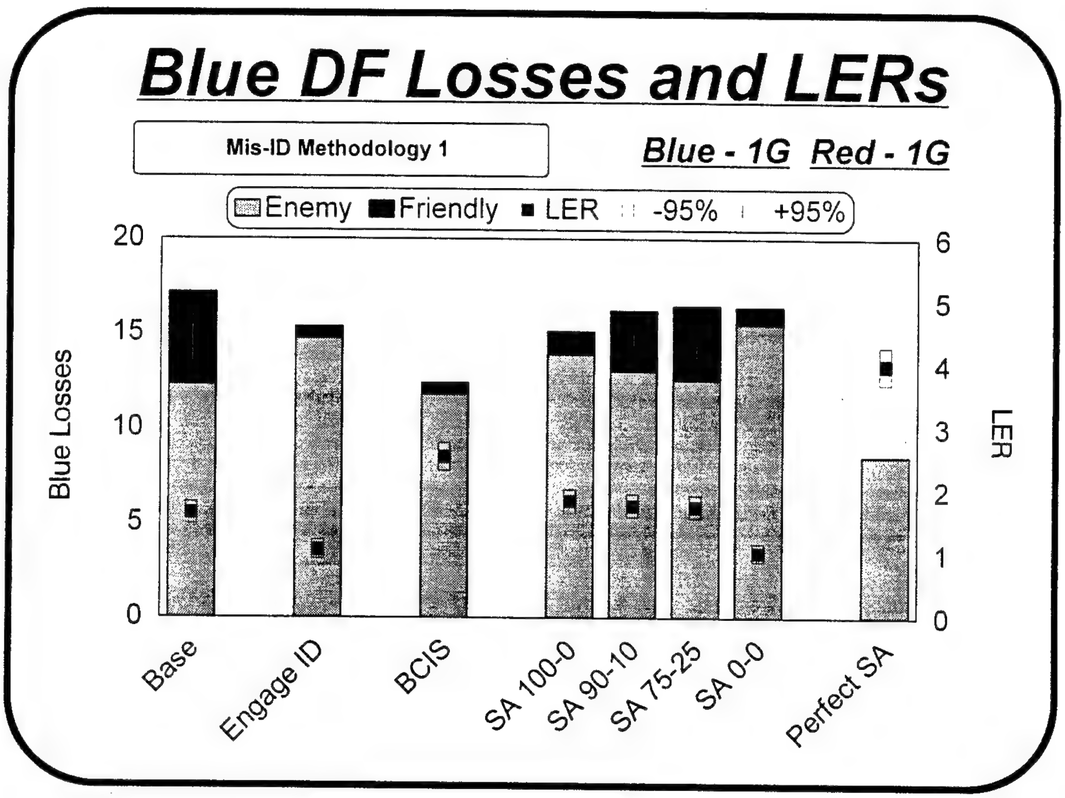

Figure 15. BLUE Direct-Fire Losses and LERs, Mis-ID Methodology 1, 1G/1G.

Figure 15 shows results for BLUE using First Generation FLIR, using mis-ID Methodology 1. Compared to the corresponding cases in the 1G/No Mis-ID cases, mis-identification of targets by BLUE results in an increase in the chance BLUE will fire at friendly targets, and will disengage from enemy targets. In general, this resulted in a decrease in BLUE force performance in all of the cases except the BCIS case. In the BCIS case, the use

of BCIS was able to prevent BLUE from engaging mis-identified friends and from disengaging mis-identified enemies. (Note: After the study, it was pointed out that it may have been more realistic to not use BCIS for deciding to engage a target that was (mis-)identified as friendly. The rationale here is that the observer would just disengage the perceived friendly target immediately and not use BCIS.) In these set of cases, BCIS showed a clear superiority in force effectiveness (LER), while also reducing fratricide to a minimum.

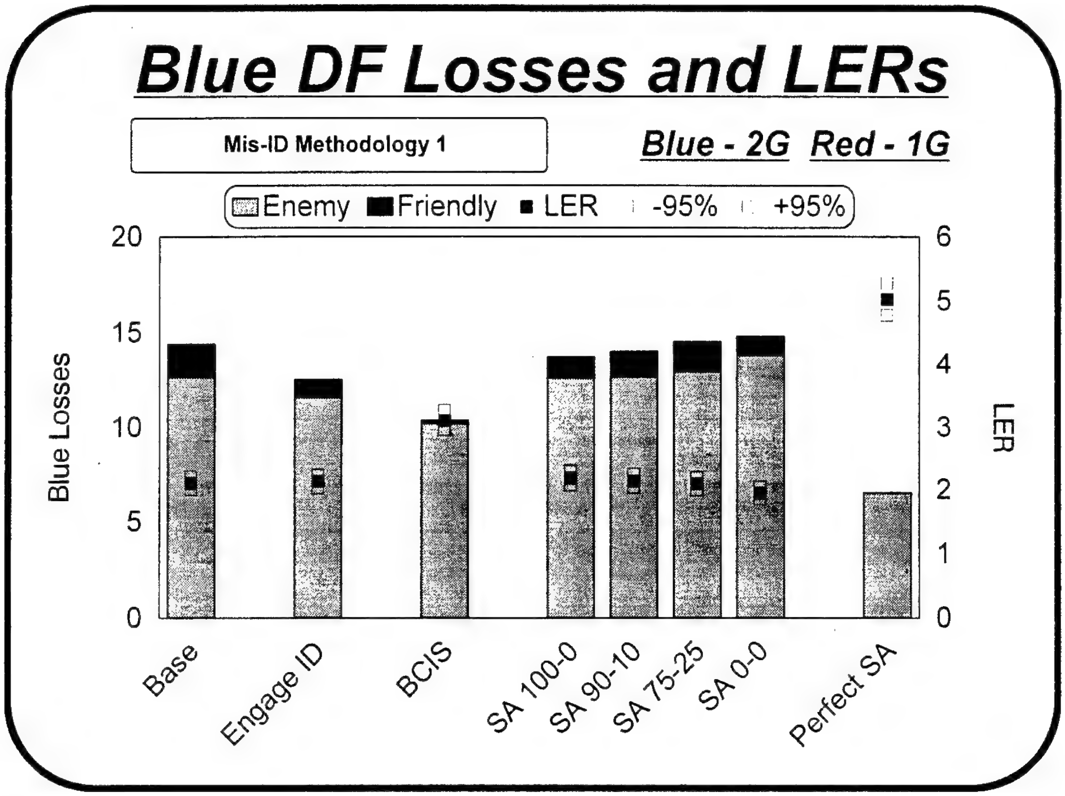

Figure 16. BLUE Direct-Fire Losses and LERs, Mis-ID Methodology 1, 2G/1G.

Figure 16 shows results for BLUE using Second Generation FLIR, using mis-ID Methodology 1. Although the incidence of fratricide is reduced compared to the corresponding cases for First Generation FLIR Mis-ID Methodology 1, the very same trends hold, showing BCIS performs best.

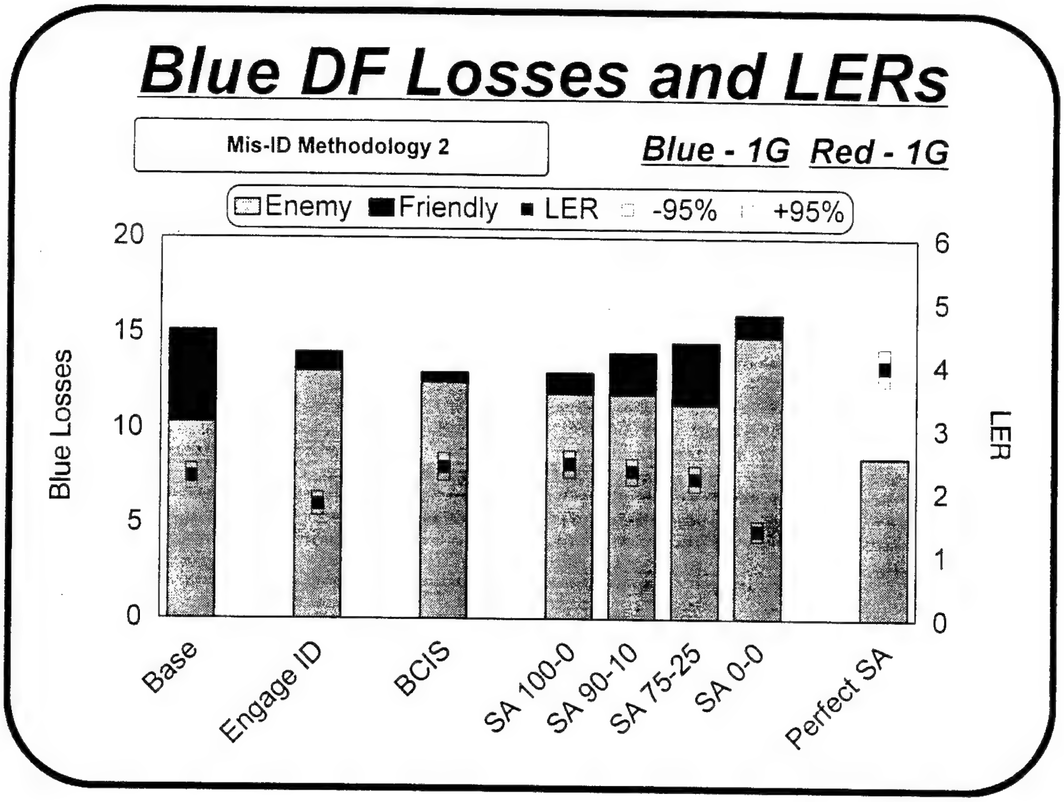

Figure 17. BLUE Direct-Fire Losses and LERs, Mis-ID Methodology 2, 1G/1G.

Figure 17 shows results for BLUE using First Generation FLIR (1G), using mis-ID Methodology 2. Using mis-ID Methodology 2 resulted in mis-identification occurring less frequently than when using mis-ID Methodology 1. Thus, there are less differences in the corresponding cases compared to no mis-ID (1G), then there were in comparing the no mis-ID (1G) cases to the mis-ID Methodology 1 cases (1G). The BCIS case still showed the best overall benefit in reducing fratricide and maintaining a good force LER.

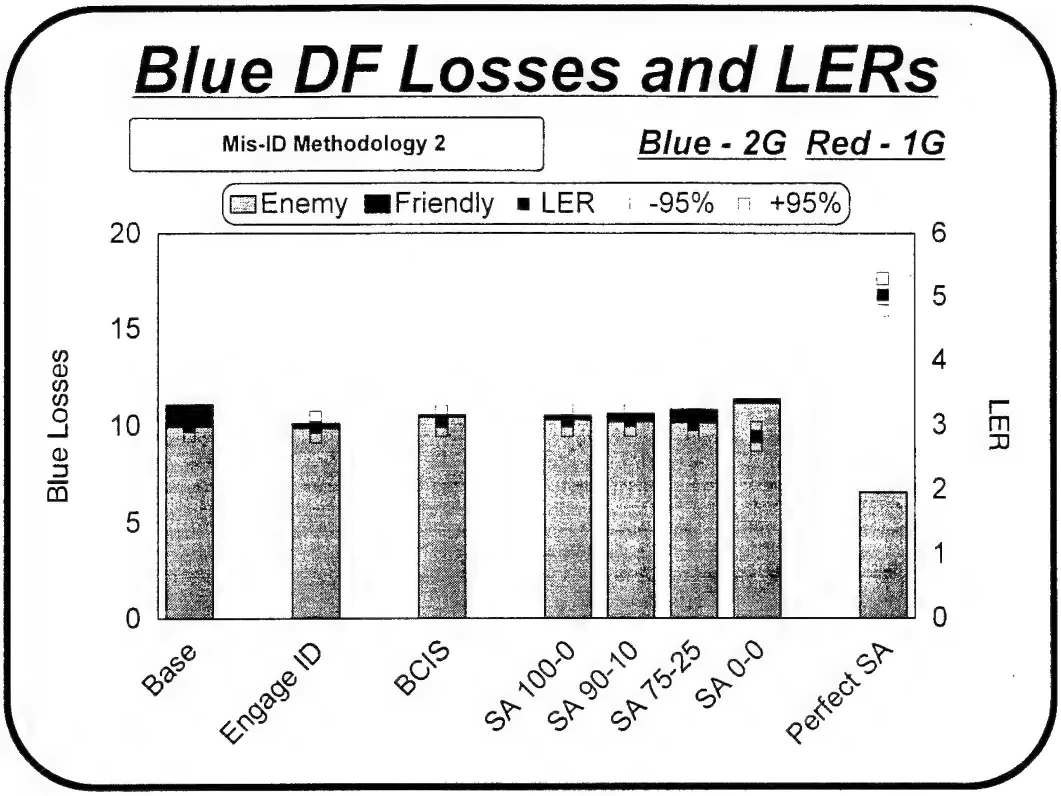

Figure 18. Blue Direct-Fire Losses and LERs, Mis-ID Methodology 2, 2G/1G.

Figure 18 shows results for BLUE using Second Generation FLIR (2G), using mis-ID Methodology 2. Unlike the results from methodology 1 (2G), these cases show about an equal benefit from all three anti-fratricidal technologies (Engage on ID with Second Generation FLIR, BCIS, and SA), although an argument can be made that BCIS performed best since it reduced the amount of fratricide by the largest percentage. Actual values are listed in the table below.

Table 6. Results for Second Generation FLIR, mis-ID Methodology 2.

Case	Total BLUE Losses	BLUE Losses due to Fratricide	LER
Base	11.08	1.12	2.99
Engage on ID	10.11	.24	2.97
BCIS	10.52	.08	3.06
SA-100-0	10.48	.20	3.07
SA-90-10	10.59	.42	3.07
SA-75-25	10.79	.65	3.01
SA-0-0	11.33	.20	2.82
Perfect SA	6.53	.00	5.03

3.5 Conclusions. Without taking into account the phenomenon of the mis-identification of targets, the following conclusions can be drawn. With BLUE using First Generation FLIR, and assuming some error in being able to assess situational awareness correctly during battle, BCIS showed the best benefit. Assuming little or no battlefield position confusion (with First Generation FLIR), either BCIS or SA showed the best performance. Using Second Generation FLIR, there was about an equal benefit from all three anti-fratricidal technologies (Engage on ID with Second Generation FLIR, BCIS, and SA).

With mis-identification of targets, Methodology 1, BCIS showed the best benefit, for both First and Second Generation FLIR use.

With mis-identification of targets, Methodology 2, BCIS showed the best benefit using First Generation FLIR, and all three technologies showed about the same benefit with Second Generation FLIR (although BCIS reduced fratricide about one-tenth of one BLUE unit more than the other two).

It is important to note that since the completion of this study, the investigation into target identification and mis-identification has continued, and 'Identification' is now defined as 'correct identification.' and an AMSAA report on target misidentification is forthcoming. Nevertheless, this report covers the methods investigated during mid 1996. It would be interesting to repeat this analysis with the new recommended mis-ID Methodology.

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2. G. Comstock, M. Schmidt, L. Harrington, B. Burns, "Groundwars Version 5.3 User's Guide," AMSAA Technical Report No. 573, March 1995.

3. M. Schmidt, "Friendly Fire and Combat Identification in Groundwars," AMSAA Technical Report No. 534, October 1992.

APPENDIX A - GIST

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APPENDIX A - GIST

AMXSY-EM

SUBJECT: Technical Report TR-610, Anti-Fratricidal Technologies Study Using Groundwars

PRINCIPAL FINDINGS: Study results showed for the zero mis-ID condition, BCIS provided significant contribution to Blue using First Generation FLIR. When Blue employed Second-Generation FLIR, all technology options (i.e., FLIR, BCIS, and SA) increased Blue effectiveness equally. For the case where target mis-ID was possible, BCIS provided the most significant reduction of fratricide and increase in Blue effectiveness.

MAIN ASSUMPTIONS: BLUE combatants were equipped with combat ID devices. Situational awareness information was available to BLUE combatants to the degree parametrically assumed during the various cases. Mis-identification cases used the emerging DISSTAF I data and the described mis-ID methodology.

PRINCIPAL LIMITATIONS: Only one scenario was examined. Situational Awareness knowledge was only used to assist in engagement decisions; no attempt was made to address broader engagement planning. Mis-identification methodologies played were based on assumptions at the time of the study (February to April 1996); current investigations (December 1996) by AMSAA suggest yet a different approach to modeling mis-ID.

SCOPE OF THE EFFORT: Groundwars Combat Simulation. Ground to ground combat simulation of a two-sided battle between heterogeneous forces. Fratricide, mis-identification, First and Second Generation FLIR, Situational Awareness, BCIS.

OBJECTIVE: Investigate first-order contributions of available anti-fratricidal technologies in a force-on-force scenario.

BASIC APPROACH:

The following combat conditions were considered: 1) Mis-ID of targets not possible,- Blue had good knowledge of Blue locations (i.e., Blue rarely engaged Blue, usually engaged Red); 2) Mis-ID of targets not possible; Blue had uncertain knowledge of Blue locations (i.e., Blue sometimes engaged Blue, disengaged Red); 3) Mis-ID of targets possible; Blue had good knowledge of Blue locations; and 4) Mis-ID of targets possible; Blue had uncertain knowledge of Blue locations. Blue would fire on classification.

Second-Generation FLIR anti-fratricidal technology option required firing on ID only.

REASON FOR PERFORMING THE EFFORT: Request of Director for Assessment and Evaluation, SARDA.

IMPACT OF THE EFFORT: First-order impact of anti-fratricidal technologies shared with Army Operations Research and Combat-ID community.

SPONSOR: U.S. Army Materiel Systems Analysis Activity

PRINCIPAL INVESTIGATOR: Gary R. Comstock

COMMENTS AND QUESTIONS:

Director, AMSAA
ATTN: AMXSY-EM, G. Comstock
Aberdeen Proving Ground, MD 21005-5071
DSN 298-2163, COM 410-278-2163

DEFENSE TECHNICAL INFORMATION CENTER (DTIC) ACCESSION NUMBER OF FINAL REPORT: Report available by contacting AMSAA's Reports Processing Center, DSN 298-5676

WHO COULD BENEFIT FROM THIS REPORT: Army Operations Research, Combat modelers, Combat-ID community.

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